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AVCAL REDUCTION ANALYSIS MODEL

by

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AVCAL Reduction Analysis Model

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ABSTRACT

This thesis provides decision makers with a model to analyze the impact of an Aviation Consolidated Allowance List (AVCAL) reduction onboard aircraft carriers (CVs). The Department of Defense (DoD) is currently down-sizing its forces by 25 percent from FY 1991 to FY 1995 due to the reduction in funding caused by the significant change in the threat assessment. The implications of the current down-sizing of forces are wide-ranging throughout DoD, including the possibility of reducing a CV's AVCAL from 90 to 60 days. Both analytical and simulation models (RP-FOR and RP-SIM, respectively) have been developed. The models measure the impact of reducing an AVCAL from 90 to 60 days by comparing the benefits of savings gained from a reduction of AVCAL, versus the penalties of reduced operatio al availability of the aircraft.

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I. INTRODUCTION

Due to the rapidly changing political scenario of events in the Soviet Union and Eastern Europe, and its implications affecting the U.S. military strategy and the Department of Defense (DoD) Budget, the Office of the Assistant Secretary of Defense is currently reviewing DoD's War Material Stockage Policy. (Office of the Assistant Secretary of Defense Memorandum, July 16, 1991)

Currently, U.S. Navy (USN) aircraft carriers (CVs) carry onboard enough stock to operate in a wartime environment for 90 days plus 17 days of stock to cover for Order and Shipping Time (O&ST). (FASOINST 4441.15F, 15 March, 1986) The proposed War Material Stockage Policy would require forward deployed units to have enough stock on hand to operate in a wartime environment for 60 days.

If the new War Material Stockage Policy is adopted, USN carriers will be required to reduce their Consolidated Shipboard Allowance List (COSAL) and Aviation Consolidated Allowance List (AVCAL) items from 90 to 60 days of stock, not including the additional 17 days of stock for O&ST.

The COSAL represents items which are required to maintain support of the ship and its equipment, except for aviation related material. The COSAL includes both repairables and consumables. A CV's COSAL generally consists of approximately 35,000

line items of a value of $23 million. Although repairables represent only about five percent of the COSAL line items, their value is approximately 50 percent of the COSAL.

The COSAL is generated by Ships Parts Control Center (SPCC) and generally incorporates the following guidelines (Moore, 1991):

- The items carried in the COSAL should be items which are components of, or provide support for, repairable equipment which is actually installed on the ship.
- They should be items which the ship's personnel are capable of replacing at sea.
- Since there are usually more such items than there is storage space aboard ship for even just one each, some items meeting the criteria above will not be carried. The decision to carry an item or not is based on forecasted quarterly demand and on the Item Mission Essentiality Code (IMEC) of the item (the value of the part to the end item).
- For an item with sufficiently high demand, the quantity carried in the COSAL is enough to meet forecasted quarterly demand with a 10 percent chance of stockout.
- The ship's Supply Officer's opinions are considered, primarily with regard to the range of items in the COSAL.

The AVCAL represents items which are required to maintain support of the Air Wing's squadrons, the CV's Aircraft Intermediate Maintenance Department (AIMD) and support equipment. The AVCAL is a specific allowance of repairable items, subassemblies and repair parts which are required for support of the assigned aircraft, engines and end items of support equipment. Consisting of consumables and repairables, the AVCAL is generated by the Aviation Supply Office (ASO) and follow basically the same guidelines as the COSAL. It is tailored in accordance with the maintenance profile of the CV and is designed to ensure maximum support effectiveness in a combat environment for a period of 90 days (NAVSUP PUB 550).

However, the AVCAL differs from the guidelines of the COSAL in the computation of the allowances because the AVCAL process takes into account not only that particular ship's usage and demand data, but also the usage and demand data of three ships with the same deckload (the type and amount of aircraft). The particular mission and the efficiency of each ship's triad of Air Wing, AIMD and Supply has a direct effect upon its demand and usage data. One CV triad can be much more efficient than another CV, and due to its efficiencies, the CV may receive an allowance less than a CV with a less efficient triad. The CV with a less efficient triad will have a higher demand and usage, resulting in higher allowances of material. To help protect the better performing triads, each CV's tailored allowance is compared to the average allowance computation of three CVs with the same deckload of aircraft. Whichever allowance computation is higher--either the individual ship or the baseline number--is accepted.

The CV's AVCAL consists of approximately 61,000 line items valued at approximately $266 million. The repairables represent almost 10 percent of the line items and almost 88 percent of the total value of the AVCAL (*USS Independence* Shipboard Uniform Automatic Data Processing System Report 008, July 26, 1991).

The objective of this thesis is to provide decision makers with a method to determine the implications of a possible reduction of a CV's AVCAL from 90 to 60 days--a method to measure the benefits (dollars saved) against the losses (a reduction in operational availability of the items affected and their resulting impact upon the system operational availability of the aircraft).

The approach taken to evaluate these impacts was to focus on a CV's Rotatable Pool (RP). The carrier's RP consist of repairable items which generally represent the following characteristics (NAVSUP PUB 550):

- Have a minimum demand of one repair a month.
- Can be repaired locally by AIMD.
- Are selected by the CV's Supply and AIMD officers.

The selection of a CV's RP was made principally because it generally represents less than 20 percent of AVCAL repairable allowances (range of 250-275 items) but will account for approximately 50 percent of all demands placed upon a carrier's repairable AVCAL (NAVSUP PUB 550)--consequently providing an outstanding barometer of measuring the effectiveness of aviation support onboard a CV.

The RP process begins with the removal of the Non-Ready for Issue (Non-RFI) repairable from the end item (the aircraft) by the organizational level of maintenance--the squadron. Once removed from the aircraft, the squadron turns in the Non-RFI repairable to the Supply Department. Supply, upon receipt of the Non-RFI repairable and the requisition for a RFI repairable replacement from the squadron, then issues an RFI repairable from its storeroom to the squadron and inducts the Non-RFI to AIMD for repair.

Upon completion of repair, AIMD returns the RFI repairable to Supply which receives and stores the item for future issue to the squadrons of the Air Wing. Non-RFI repairables which AIMD is either unable or unauthorized to repair are considered Beyond

Capability of Maintenance (BCM) and are returned to Supply for shipment for Depot level repair located ashore.

The USN, in its allowance comp:ıations for RP items, currently provides approximately a 95 percent stock-in probability with only a five percent stock-out probability. (FASOINST 4441.15F, 15 March, 1986)

The RP operational procedures closely resemble the basic inventory queue, with a one-for-one replacement. Except the queue is multi-echelon with two sources of repair--field level and depot level, and two sources of supply--the CV and the supply system (intermediate and wholesale levels of supply). The CV is a field level supply activity issuing the RFI spares from the RP and the supply system issues repairables on a one-for-one exchange basis when a BCM occurs.

None of the literature survey relating to the analysis of inventory/repairable queues exactly replicated the RP operational procedures with the two levels of repair and two levels of supply. The unique factor of this thesis is that a model is provided which accurately and realistically resembles the RP operation, including the two levels of repair and supply, the BCM attrition, and the implementation of real data.

In conducting a literature survey, the focus was strictly limited to inventory queues, spare provision, general repairable item inventory controls, finite source queueing models and simulation.

There were several good pieces of work with regards to spares provision which were consulted. They included Gross and Ince (1978), Gross, Kahn, and Marsh (1977), and Gross (1982). Basically they dealt with a one-for-one replacement and did not

provide any examples of the RP operation or impact of a CV AVCAL reduction. Tedone (1989) provided a similar problem as this thesis, except the variables consisted of only a single source of supply and repair. It discussed the problem for American Airlines in attempting to allocate 5,000 line items to stations to satisfy all expected demands, at the lowest possible costs:

> Our desire was to distribute repairables to stations in a cost-effective manner, balancing the cost of part ownership against the cost of part shortage while maintaining an acceptable level of availability. The problem is to find the allocation of least total cost.

Another difference in comparing the American Airlines' problem with the USN's is that American Airlines has a secure, always functioning short logistical pipeline with no threat of interruption.

Gross, Miller and Soland (1983) did address the situation of having two sources of repair and supply. But its main focus was the "study of the trade-offs possible among spares levels and repair capacities, as well as a more realistic model than is presently available of the underlying stochastic process that describes components which randomly fail and require repair." They mentioned the multi-echelon repairable-item model named METRIC (Feeney and Sherbrooke, 1966) which is best described as:

> A natural model for repairable-item situations in that when an item fails, it is generally dispatched immediately to a repair facility and a spare, if available, is issued. A key assumption of these METRIC models is commonly known as the ample service assumption. This means that repair capacity is infinite, that there is never any queueing of items waiting for a repair channel.

Although the model of thesis does include dual sources of repair and supply, it only models the retail site repair and supply operations and the repair capacity of AIMD is

most definitely finite and delays with resulting queues will occur onboard a deployed and operating CV.

The model used in this thesis was devised to resemble the operational procedures of a RP within the following boundaries:

- Selection of one CV (*USS Independence* CV-62) and its attached Carrier Air Wing (CVW-14).
- Selection of one aircraft type (F/A-18 Hornet).
- Selection of one sixth-month deployment by CV-62 (20 June-to-20 December, 1990--which coincided with Operation Desert Shield) and its pertinent data with regards to end item population, arrival rate for repair, and BCM rate.
- Selection of allowance level computations for 90 and 60 days were based upon FASOINST 4441.15F of 15 March, 1986, and Commander Naval Air Force U.S. Pacific Fleet (COMNAVAIRPAC) Code 45 to compute any possible allowance differences of F/A-18 RP items.

The objective of this thesis is to provide decision makers with a method that can evaluate the impact of reducing a CV's AVCAL from 90 to 60 days. We developed two models, the RP-FOR and RP-SIM models, for this thesis. The RP-FOR model is an analytical model written in FORTRAN. It is based on the finite source queueing model with spares discussed in Gross and Harris (1985). The RP-FOR uses one source of supply and does not consider the BCM process. The RP-SIM model is a simulation model which takes into account the BCM process. It is written in SIMAN, simulation language (Pegden, et. al., 1991). The models can be easily adjusted to allow decision makers to evaluate the impact of enlarging or reducing a CV's AVCAL to any size. The model can be enlarged to include all of the squadrons of an Air Wing, and even all of the Air Wings in the fleet. The decision makers can properly evaluate the gains (financial

savings achieved with less items carried onboard) against the loss of operational availability of the aircraft based upon the availability, or lack of the component in the RP (defined as $A_o(i)$) and the percent of time the aircraft is operational due to the availability of the spares as a whole within the RP (defined as $A_o(rp)$).

Chapter II of the thesis reviews the background material of the problem statement. It consists of the catalysts of Office of Secretary of Defense's proposal for reduction of War Material Stockage and the resulting implications. Additionally, it goes into depth of the inter-workings of carrier aviation support including the CV departments of Supply and AIMD and the assigned Air Wing. Chapter III reviews the AVCAL computation specifics of the model and Chapter IV evaluates the impact of a reduced AVCAL onboard a CV with a pair of models, the RP-FOR model for a quick impact review and the RP-SIM model for a more detailed analysis of the AVCAL reduction. Chapter IV is the analysis of the results. Chapter V consists of the summary and conclusions of the thesis.

II. BACKGROUND

A. THE CATALYSTS FOR CHANGE

The significant changes of the political structure of Eastern Europe, followed by the Soviet Union, in the early 1990's have made a dramatic impact upon the threat assessment upon the U.S. It began with the collapse of the Berlin Wall and a mass exodus of East Germans to West Germany via Romania and was followed in succession by:

- The unification of West and East Germany.
- The transition from communism to democracy in Eastern Europe.
- The disbandment of the Warsaw Pact.
- The failed coup attempt in August 1991 against Soviet President Mikhail Gorbachev combined with the resulting acceptance of democracy by the Soviet Union and its Republics.

These incredible political changes which occurred at break-neck speed has substantially reduced the threat of global military conflict with the Soviet Union. The threat has been so severely reduced that U.S. President George Bush declared, "the prospect of a Soviet invasion into Western Europe is no longer a realistic threat" and then proceeded to announce unilateral reductions in the U.S. nuclear arsenal including the standing down of all United States Air Force strategic bombers and the withdraw of all tactical nuclear weapons onboard naval ships (Morganthau, T. et. al., 1991).

This significant threat reduction and the insurgence of regional conflicts upon U.S. national interests (Invasion and temporary occupation of Grenada in 1983, and Panama in 1989, and Operation Desert Storm against Iraq in 1991) have led DoD to switch its threat assessment from a global confrontation with the Soviet Union to regional contingencies.

B. IMPLICATIONS

Although the revised threat places a greater emphasis on mobility of U.S. forces, the resulting change in the threat assessment has made a negative impact upon DoD funding. The DoD is currently down-sizing its forces by 25 percent from FY 1991 to FY 1995 due to the reduction in funding caused by the significant change in the threat assessment.

Due to the decrease in DoD funding, President Bush tasked DoD to conduct a comprehensive review to identify any economies and efficiencies which could be implemented to better manage DoD with lower costs. This led Secretary of Defense Richard Cheney to announce in July 1989, the initial Defense Management Review (DMR):

> The number one goal of the initial DMR was to identify savings totaling $30 billion during the period of FY 1991-1995. The primary focus throughout was on reducing the cost of the support infrastructure. Dollars saved through effective initiatives on the support side can help preclude further or deeper reductions in force structure and personnel. (Arthur, S.R. Vice Admiral et. al., 1990)

The initial DMR led to several Defense Management Review Directives (DMRDs) which increased the projected five-year savings from $30 billion to $39 billion. Within

the projected $39 billion of savings, $21 billion was projected in the category of logistics. The DMRD with the most significant impact on the supply infrastructure was *DMRD 901: Reducing Supply System Costs.*

DMRD 901 projects a savings of $2.5 billion for the USN. It consists of four potential saving areas:

- Reductions in Procurement Lead Times.
- Buy Our Spares Smart generated price reductions.
- Reductions in Intermediate Level inventories.
- Reductions in Consumer Level inventories.

The reduction in consumer level inventories is particularly aimed at:

- Increasing the use of readiness based spare allowance models.
- Reducing the range of insurance items carried on each ship and consolidating the stockage of these items ashore, and /or onboard Combat Logistic Force ships.
- Reducing the safety level for aviation repairables at ashore activities.

It is the sought-after reduction in consumer level inventories which has prompted the Office of the Assistant Secretary of Defense to propose the revision of the War Material Stockage Policy.

The principal objective of the newly proposed War Material Stockage Policy is "to acquire and maintain inventories of war material sufficient to sustain wartime operations for committed forces for sixty (60) days from the time forces are initially committed." (Office of the Assistant Secretary of Defense Memorandum of July 16, 1991)

Revising the current policy of USN CVs maintaining a 90 day allowance of stock to an allowance of only 60 days of stock--a 30 day reduction of a carrier's AVCAL--leads to some considerable implications.

First and foremost would be the significant savings in dollars. A CV's consumer level inventory is represented by its Ship Allowance Level (SAL). Currently, CV's have a SAL of approximately \$294 million representing approximately 106,500 line items. Within the SAL, the AVCAL accounts for approximately \$266 million and 61,000 line items. Within the AVCAL, the repairables account for approximately \$234 million and 5,800 line items (*USS Independence* Shipboard Uniform Automated Data Processing System (SUADPS) Report 008, July 26, 1991).

It is conceivable that a reduction of 30 days of the CV's SAL could possibly result in the savings of approximately \$100 million per carrier and with a planned fleet of 12 carriers, that could amount to a one-time savings of approximately \$1.2 billion.

The trade-off of the financial bonanza would be the degradation of operational readiness of the affected items and the corresponding impact upon system availability of the particular aircraft, measured by the reduction of operational availability due to a lower allowance of RFI spares.

C. CARRIER AVIATION SUPPORT

1. The Mission and Responsibilities

The specific missions and responsibilities of the USN are to establish and maintain control of sea and air space, to project power ashore as required, and to

represent U.S. interests and policy. The change of the threat assessment from a global conflict with the Soviet Union to regional contingencies has resulted in significantly improving the value of today's CVs.

With approximately 75 percent of the earth's surface covered with the world's oceans, the CV with its unlimited range and endurance (especially the nuclear carriers--of which the USN currently has six operational with another three under construction) coupled with high speed (30+ knots) provides the absolute weapon system in mobility and sea control with no concern or worry of another nation's boundaries or restrictions. An absolute key ingredient to combat regional contingencies.

The 90,000 ton CV (and 1,100 feet in length) provides a self-contained base with an abundance of repair capability for itself and its attached Air Wing. The floating fortress carries approximately 86 aircraft and 5,500 sailors capable of logistically operating in a wartime environment for 90 days without resupply. Its only restrictions would be the amount of ammunition and aviation gas the ship and its respective battle group has on hand.

The USN CVs are by far the mightiest and most powerful warships in the history of sea warfare. They best represent Civil War Confederate General Nathan Bedford Forrest's axiom, "The key to winning a battle is to get there firstest with the mostest."

2. The triad of Aviation Support

Aviation readiness is measured by the computation of the Air Wing's overall Mission Capable (MC) and Fully Mission Capable (FMC) rates with regards to its

onboard aircraft. If an aircraft is capable of fulfilling either partially or all of its mission requirements, it is considered to be MC. If an aircraft is capable of fulfilling all of its requirements, then it is considered to be FMC. The MC and FMC rates are calculated by dividing the amount of aircraft which are MC and FMC, by the total amount of the Air Wing's assigned aircraft in reporting status. For example, if CVW-14 had 100 aircraft in reporting status, with 89 aircraft either partially or fully mission capable, and a total of 85 aircraft fully mission capable, then its MC and FMC rates would be 89 percent and 85 percent respectfully.

When the aircraft are partially mission capable (PMC) or grounded (non-operational), it is because of either maintenance or supply. If all of the required parts are on hand and the aircraft is under repair or, if all of the parts are on hand and one or more of the required parts are repairables which are currently being repaired by AIMD, then because of maintenance, the aircraft is PMC or grounded.

If any of the required parts are currently not on hand for any reason and the requisition(s) for the part(s) are off-ship, then because of supply, the aircraft is considered PMC or grounded. Within the supply channels, if an aircraft is PMC due to supply, then the respective off-ship requisition is said to be Partially Mission Capable because of Supply (PMCS). If the aircraft is grounded because it is unable to fly or conduct any of its missions due to supply, then the off-ship requisition is said to be Not Mission Capable because of Supply (NMCS).

The status of the Air Wing and its aircraft combined with the efficiency of the onboard aviation support is reported via a daily message (while the CV is at sea)

called the Aviation Material Readiness Report (AMRR). The AMRR is a capsulized situation summary of the CVs operational and logistics posture. The confidential message is received and reviewed from the Chief of Naval Operations to the various Commanders-In-Chief, to the Type Commanders (TYCOMs) and every naval activity in the operational, maintenance and logistic communities.

The AMRR lists by squadron all of the Air Wing's aircraft as either being PMC, FMC or Not Mission Capable (NMC). The AMRR then lists the reason affecting the aircraft's status--may it be either due to maintenance or supply (PMCS or NMCS). The AMRR can be compared to a daily report card of the efficiency of the aviation support of the CV's triad: The Air Wing and its composite of squadrons, AIMD, and Supply.

USS Independence's attached Air Wing, Carrier Air Wing Fourteen (CVW-14) represents the latest deckload configuration of USN CVs (see Figure 2(A)). It includes the latest aircraft to enter the fleet (the F/A-18 Hornet) and is the prototype for all future Air Wings within the USN.

Squadrons	Aircraft Type	Amount of Aircraft
VF-21	F-14A Tomcat	12
VF-154	F-14A Tomcat	12
VFA-25	F/A-18 Hornet	12
VFA-113	F/A-18 Hornet	12
VA-196	A-6E Intruder	10
VA-196	KA-6D (Tanker)	4
VAQ-139	EA-6B Prowler	4

VAW-113	E-2C Hawkeye	4
VS-37	S-3B Viking	10
HS-8	S-3H Sea King	6

Figure 2(A)--CVW-14 Deckload onboard *USS Independence*

The combined efforts of the triad are reflected in the AMRR. The actual readiness indicators (which reflect the efficiency of the aviation support) are the PMC and FMC rates coupled with the total count of the off-ship NMCS and PMCS requisitions.

Each CV has onboard prior to deployment an AVCAL of spare parts consisting of consumables and repairables to support its Air Wing for 90 days of wartime operations. Supply department is tasked with properly managing (in addition to the COSAL) approximately 61,000 aviation consumable and repairable items valued at approximately $266 million. The management includes inventory accuracy, maintenance of safety levels, proper reorder amounts and frequency of reorders, proper receipt and stowage of incoming repair parts for later issues, and 100 percent accountability of its approximate 5,800 repairables valued at over $233 million.

AIMD is responsible for inspecting engines, repairing components, using diagnostic and automatic test equipment, testing and evaluations, and removing and replacing components. The more efficient AIMD is in receiving, repairing and returning RP items to Supply (which will receive, stow and later issue as demanded by the

squadrons of the Air Wing), the lower will be the stock-out probability of the RP items and less RP items will be BCM'd for Depot level repair.

Finally, the maintenance ability of each squadron comes into effect. Each squadron has its own organizational level of maintenance which is tasked with daily maintenance requirements, tests and inspections and removal and replacement of faulty parts. Poor maintenance on their part can severely impact on the workload of AIMD and Supply.

The teamwork and the aviation support efficiency of the triad is one of the "two" key variables determining the aviation readiness. The other significant variable is the daily sortie rate. A sortie is the launch of one aircraft. Very similar to an automobile, aircraft perform better and break less if they are used often. However, if flown too much, the aircraft will start to break. Finding the optimum sortie rate of an aircraft with regards to its impact upon aviation readiness can be "compared" to finding the best speed to obtain the optimum miles per gallon for an automobile.

The optimum sortie rate for most CV triad's is generally considered to be approximately 65 to 75 sorties a day with one no-fly day a week. Once the daily sortie rate begins to climb into the 80's and higher, the readiness numbers will begin to deteriorate as the off-ship NMCS/PMCS count increases due to the AVCAL being expended faster than the logistical pipeline can replace it. In addition, the queue at AIMD begins to suffer from an ever increasing backlog of items awaiting repair as more items break due to an increase in the sortie rate.

Prior to the Reagan era build-up, an off-ship daily average NMCS/PMCS count of approximately 50 requisitions for a deployed CV was considered good. A count of 30 was considered exceptional. However, by the late 1980's, it was common place for excellently operating triads to daily average around 20 off-ship NMCS/PMCS requisitions and for exceptional triads to daily average approximately 10 off-ship NMCS/PMCS requisitions during a six-month deployment.

III. THE MODEL

A model has been developed to determine the impact of a reduction of AVCAL upon a CV's RP. The positive impact of such a reduction would be the dollar savings of a reduced AVCAL. The negative impact would be the reduction of operational availability of the affected items resulting in the corresponding reduction of the system availability of the aircraft, due to having less RFI spares onboard. The model had to be realistic, logical, and accurately reflect the operation of a RP with its association with AIMD.

A. DESCRIPTION OF THE MODEL

1. RP Allowance Requirements

The RP consists of field level repairables which are locally repaired by AIMD. The computation of the fixed allowance levels for repairables is provided in Enclosure (2) of FASOINST 4441.15F (15 MAR 1986). The allowance computation is based on the sum of the Raw Attrition Quantity (defined as the number of field level repairables which AIMD is unable to repair and are shipped off-station for depot level repair--a BCM action) and the total Local Repair Cycle Requirements (LRCR) Quantity (defined as the average number of spares required to maintain a certain protection level while the component is being repaired).

The Raw Attrition Quantity formula is stated below:

$$\frac{\text{Total Number of BCM's during period of database}}{\text{Total Flying Hours during period of database}} \times \begin{array}{l}\text{Requisitioning}\\ \text{Objective at}\\ \text{future wartime}\\ \text{flying hours}\end{array}$$

The period of database generally used is for 12 months. However, the period of database is for the amount of flying hours flown while a particular type of aircraft is onboard the CV while the CV is operating at sea. In addition, the Requisition Objective (RO) is defined as the amount of proposed future flying hours. If the proposed amount of flying hours is the same amount as was used in the period of the database, the Raw Attrition Quantity would equal the total number of BCM's during that period of the database. Likewise, if the RO is larger than the amount of flying hours used in the period of the database, then the Raw Attrition Quantity will be larger than the total number of BCM's during the period of the database which was used. In order to maintain the thesis as an unclassified document due to the classified nature of the amount of flying hours used or proposed, an attrition formula used by COMNAVAIRPAC, Code 45 was selected and later validated by the AVCAL branch at ASO, Code 03411X. The unclassified Raw Attrition Quantity formula is stated below:

$$\frac{\text{Total Number of BCM's during period of database}}{\text{Total amount of days in period of database}} \times \text{107 days}$$

The total number of days selected to be used in the database was 180 days. Although the database period covered was for one year (365 days), the amount of days in which the

CV is considered to be operating at sea during the period of one year is generally considered to be 180 days. The 107 days in the right hand side of the above equation represents the 90 days of authorized AVCAL plus an additional 17 days of O&ST as stated in the FASOINST 4441.16F.

To obtain the attrition allowance for 60 days of authorized AVCAL, the total number of days in the right hand side of the above equation would be 60 days plus the 17 days of O&ST for a total of 77 days instead of 107 days.

The Raw LRCR Quantity formula (stated below) is used to assist in obtaining the total LRCR quantity.

$$\frac{\text{Number of site repairs during period of database}}{\text{Number of days in database}} \times \text{Average TAT}$$

The Raw LRCR quantity represents the expected number of repairs during the turn-around-time (TAT) while the component is repaired in AIMD. The computed quantity is then applied to Attachment (A) of FASOINST 4441.15F in order to calculate the total LRCR quantity, which ensures a certain protection level of RP spares during the TAT.

The average TAT of the Raw LRCR quantity formula includes the time it takes measured in days from removing the Non-RFI repairable from the end item, the scheduling time required to do the entire maintenance action, the time awaiting for parts (AWP) if required, and the actual repair time by AIMD. The instruction, FASOINST

4441.15F stipulates that constrained TAT will be used. The Constrained TAT is defined as the maximum allowed time measured in days an element can be documented and reported for allowance computations utilizing AV-3M procedures (a system which the USN uses to record all pertinent data relative to all specific maintenance actions). Constrained TAT is principally used to prevent a very poorly operated triad to be rewarded with a larger allowance while a very efficiently operated triad would be penalized with a lesser allowance. The constraints are as follows:

Element	Maximum Allowed Time (Days)
Removal to AIMD	1
Scheduling Time	3
Awaiting Parts	20
Actual Repair Time	8

The required input data for allowance computations are obtained from AV-3M database which originates onboard the CV as a Support Action Form (SAF) (OPNAV 4790/42), material source document (DD 1348) or from the Visual Information Display System/Maintenance Action Form (VIDS/MAF, OPNAV 4790/60) which is used for recording all pertinent data relative to specific maintenance actions (NAVSUP PUB 550). The SAF is used to document hours expended by maintenance personnel in functions other than corrective maintenance.

From the time the Non-RFI repairable is removed from the end item until repair is completed, all pertinent supply and maintenance actions are documented and reported utilizing the AV-3M system. The CV will submit a monthly AV-3M data tape to the TYCOM, who will forward the information to Naval Material Support Office where it is passed to the Navy Automated Logistics Data Center (NALDA) database located at ASO. The NALDA system provides customer service (by providing information retrieval service for DoD personnel and activities) either through on-line query or by extracting applicable required information utilizing the various NALDA system databases.

2. Computations of Allowance Quantities

An example of computing the fixed allowance for a repairable is provided (the period of the BCM's incurred and attrition database must cover the identical period of time). Suppose there were five BCM's during the 180 day period of the database, the Raw Attrition Quantity for a 90 day AVCAL is (5 BCM's X 117 days) / 180 days = 3.25. The Raw Attrition Quantity for a 60 day AVCAL would be (5 BCM's X 77 days) / 180 days = 2.1388. The Raw Attrition Quantity must be equal to or greater than one in order for the CV to qualify for an attrition allowance of one or more. If the Raw Attrition Quantity is greater than one, then the total is rounded-off.

Because the Raw LRCR Quantity does not factor into account the amount of authorized days in an AVCAL, its individual computation will not change as the AVCAL is reduced from 90 to 60 days. Its computation will be the same for both 90 and 60 day

AVCALs. Suppose that a total of 50 repairs of a certain RP is recorded for a 180 day period, then the Raw LRCR Quantity would be (50 Repairs / 180 days) X 2.1 days = .5833.

The FASOINST 4441.15F then applies the computed quantity to attachment (A) of the instruction in order to calculate the total LRCR quantity. The computed factor of .5833 would equate to a total LRCR Quantity of 2. The LRCR quantity provides an approximate 95 percent protection level from stockout during the TAT. In other words, the attachment calculates a LRCR stock allowance assuring a 95 percent probability of stock being available when requested.

The computation results of the allowances of the example are provided in Figure 3(A).

	Raw Attrition Quantity	Raw LRCR Quantity	Sum Total
90 day AVCAL	3	2	5
60 day AVCAL	2	2	4

Figure 3(A)--Sum total AVCAL quantities for 90 and 60 days

Calculations of the Raw Attrition Quantities and the Raw LRCR Quantities were computed for the F/A-18 Hornet RP items onboard *USS Independence*. *USS Independence* was selected because she has been assigned the most modern and up to date

Air Wing composition. The F/A-18 Hornet was selected because it is the latest aircraft to join the USN inventory and will most likely be in service for the next 15 to 30 years.

A complete listing of *USS Independence* RP was obtained from COMNAVAIRPAC, CODE 45. The allowance for 90 and 60 day AVCALs for all repairables applicable to the F/A-18 Hornet were computed using the methodology described above. All AV-3M data requirements to make the computations were obtained from NALDA. The standard price of all F/A-18 Hornet applicable RP items which received a reduction in allowance due to the reduction of 30 days of AVCAL were obtained from Commander Strike Fighter Wing U.S. Pacific Fleet.

The RP listing furnished by COMNAVAIRPAC listed 272 line items. However, NALDA only had verifiable data for 235 line items. The RP listing included 47 RP items for the F/A-18 Hornet (see Appendix A), of which 15 did not have any verifiable AV-3M data from NALDA. Of the remaining 32 line items, 16 items have no change in attrition allowance with a 30-day AVCAL reduction. The 16 line items which did suffer from an attrition allowance reduction due to the 30 day reduction in AVCAL, are listed in Table 3.1 in NIIN sequence with their total number of site repair receipts, average constrained TAT, total number of BCM's, their computed allowances, unit price of each item and the corresponding dollar savings.

TABLE 3.1--*USS INDEPENDENCE* F/A-18 RP ITEMS RECEIVING AN ATTRITIONAL AVCAL REDUCTION WITH APPLICABLE AV-3M DATA (FROM THE PERIOD OF 20 JUNE TO 20 DECEMBER, 1990) TO COMPUTE 90 AND 60 DAY ALLOWANCES

NIIN	# OF SITE REPAIRS	TAT	BCM	90 DAY ALLOW	60 DAY ALLOW	UNIT PRICE ($)	SAVINGS ($)
01-093-1491	13	4.2	3	3	2	10,230	10,230
01-119-0647	28	5.9	2	3	2	69,490	69,490
01-123-2204	75	0.7	70	42	30	11,880	142,560
01-129-3954	7	0.3	3	2	1	479	479
01-131-8104	13	0.3	5	3	2	914	914
01-144-0132	5	8.7	2	1	0	20,370	20,370
01-156-7310	37	3.8	2	3	2	67,330	67,330
01-158-9694	9	0.4	5	3	2	21,560	21,560
01-163-6062	44	1.3	12	7	5	99,270	198,540
01-201-3256	29	1.4	3	3	2	3,880	3,880
01-220-4768	6	20.0	7	6	5	83,100	83,100
01-232-8815	40	0.5	24	14	10	18,080	72,320
01-240-5562	59	1.6	2	3	2	77,410	77,410
01-247-5025	39	2.9	2	3	2	373,280	373,280
01-271-4573	74	4.5	3	6	5	130,840	130,840
01-278-9291	18	6.9	3	4	3	23,330	23,330

The database to compute the 90 and 60 day allowances in Table 3.1 covered a period of 180 days. The number of site repairs and TAT are used to compute the Raw LRCR quantity to assist in obtaining the total LRCR Quantity. The total number of BCM's is used to compute the Raw Attrition Quantity. The total allowance computation is based on the sum of the Raw Attrition Quantity and the total LRCR Quantity.

The results in Table 3.1 indicates a possible savings of $1,295,633 from a 30 day reduction of AVCAL. In Chapter IV, the trade-off between the cost savings and the reduction in effectiveness will be investigated.

B. ASSUMPTIONS AND SCOPE

The major assumptions used in the AVCAL computations are the following:

- The amount of actual flying hours would be independent and unaffected by the 90 to 60 day reduction in AVCAL.
- Due to the assumption that the amount of flying hours would be independent and unaffected by the reduction in AVCAL, the maintenance data (AV-3M) would remain approximately the same with little or no significant change.

The scope used in this thesis was very narrow. Time and resource constraints did not allow more than a single approach to the problem of a reduction in AVCAL. There is more than one method to analyze an AVCAL reduction. Other procedures include reducing the AVCAL from 90 to 60 days but use unconstrained TAT and unconstrained TAT elements in the AVCAL computations. For example, compute an AVCAL reduction from 90 days of constrained TAT to 60 days of unconstrained TAT. An AVCAL reduction model could also focus on computing an AVCAL reduction of all items with an IMEC which will not ground the aircraft, while not reducing the items with an IMEC

which will ground the aircraft. The scope used in this thesis took the approach of focusing strictly on allowance computations with no exceptions. The following boundaries were made to shape the scope of this thesis:

- Only considered RP items. Did not consider any computations of Non-Pool items, whole engines or F/A-18 engine modules, interim support, or consumables.

- Did not consider the possible impact of a consumable reduction and its effect upon AWP and AWP's impact upon increasing TAT which would increase the Raw LRCR quantity of repairable allowances.

- Did not consider reduction of AVCAL by taking into account the IMEC of an item, the code which defines the importance or relative importance of a part to the mission of the aircraft. If for example the failure of an item would ground the aircraft, it would be assigned a IMEC of 1. An approach could be taken to reduce an AVCAL by 30 days but only reduce the line items with a non-vital IMEC.

- Did not make any comparisons of 90 and 60 day AVCAL based on constrained and unconstrained TAT. It is possible that a 60 day AVCAL using unconstrained TAT could be higher than a 90 day AVCAL using constrained TAT.

IV. ANALYSIS

Upon completion of computing the 90 and 60 day allowance levels of the 32 F/A-18 Hornet RP items, 50 percent of the line items suffered from a reduction of allowances due to BCM attrition. It was simple to compute the gain of the reduction by simply multiply the amount of reduction times the standard unit price of the RP repairable. (The total savings illustrated in Table 3.1 is $1,295,633.) However, the process to compute the loss of such a reduction based upon operational availability of the affected item and the corresponding impact upon the associated aircraft system availability was much more difficult. Two models were devised to ascertain the impact an AVCAL reduction would have on the operational availability of the affected item.

A. RP-FOR MODEL

1. Input Requirements

A finite source queueing model, discussed in Gross and Harris (1985) was first examined in an attempt to properly ascertain the loss of operational availability due to a reduction of AVCAL. The finite source queueing model was translated into a FORTRAN program for implementation (see Figure 4(A) for the finite source queueing model equations which were translated into the FORTRAN program).

K: number of aircraft (AC)
Y: number of spares
λ:failure rate/AC/unit time
μ: number of repair channels
P_n: probability of n customers (engines) in the shop

* Failure time and service times are exponentially distributed

i) if c $\le$ Y,

$$P_n = \begin{cases} \dfrac{K^n}{n!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (0 \le n < c) \\[2ex] \dfrac{K^n}{c^{n-c}c!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (c \le n < Y) \\[2ex] \dfrac{K^Y K!}{(K-n+Y)!\,c^{n-c}c!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (Y \le n \le Y+K) \end{cases}$$

ii) if c > Y,

$$P_n = \begin{cases} \dfrac{K^n}{n!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (0 \le n < Y) \\[2ex] \dfrac{K^n K!}{(K-n+Y)!\,n!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (Y+1 \le n < c) \\[2ex] \dfrac{K^Y K!}{(K-n+Y)!\,c^{n-c}c!}\left(\dfrac{\lambda}{\mu}\right)^n P_0 & (c \le n \le Y+M) \end{cases}$$

Solve for P_0 using

$$\sum_{n=0}^{Y=M} P_n = 1$$

Then

$$number\ of\ AC\ grounded = \sum_{n=Y+1}^{Y+M} (n-Y)\,P_n$$

Figure 4(A)--Finite Source Queueing Model with Spares (Gross & Harris, 1985)

For further details and explanation of the finite source queueing model in Gross and Harris.

The FORTRAN program of the finite source queueing model is easy to use. Appendix B is the listing of the RP-FOR model used in the AVCAL reduction. It requires only five variables for data input prior to execution of the program:

- The number of aircraft, which in this thesis scenario is 24, which represents the sum total of two F/A-18 squadrons of 12 aircraft each, assigned to CVW-14 onboard *USS Independence*.
- The number of repair channels is one.
- The number of spares, which represents the AVCAL quantity which was derived from the 90 and 60 day AVCAL computations.
- The failure rate per component per day, which is assumed to follow Poisson distribution..
- The service time is the time it takes for AIMD to repair the Non-RFI item, which is assumed to follow exponential distribution..

Upon execution, the output of the RP-FOR model include the following results:

- Probability of stockout, which is the probability that a demand for a RFI spare will occur and no RFI spares are currently available for immediate issue.
- Average number of spares in AIMD, which represents the amount of Non-RFI items which are in the AIMD repair system.
- Average number of spares in the repair queue, which represents the amount of Non-RFI items awaiting to be serviced by AIMD.
- Average number of aircraft grounded, which represents the amount of aircraft grounded due to no RFI spares being available for issue to replace the Non-RFI items which were removed from the end item for repair by AIMD.
- TAT, measured in the unit of days, to remove the Non-RFI item from the end item and replace it with a RFI item.
- Operational availability of aircraft, which represents the percentage of each aircraft being operational at any one time. It is calculated by taking the total number of aircraft (24) and subtracting from it the average number of aircraft grounded and dividing that total by the total number of aircraft (24).

Once the RP-FOR model produces the average number of aircraft grounded, it must be used to obtain the operational availability of the aircraft based upon the availability of the component ($A_o(i)$). For example, a component with an $A_o(i)$ of .95 means that from a pool of 100 aircraft, 95 will be available and five will be grounded due to the availability of that component assuming the remaining components are fully available. The A_o of the aircraft in the RP-FOR model is defined as the number of available aircraft (total number of aircraft - number of aircraft grounded) divided by the total number of aircraft:

$$A_o = \frac{\text{Number of Available Aircraft}}{\text{Total Number of Aircraft}}$$

2. RP-FOR model data input

A total of 24 aircraft was selected to represent the two F/A-18 squadrons (of 12 aircraft each) assigned to *USS Independence*. An assumption of one repair channel was made. The number of spares used were taken from the computation results listed in Table 3.1.

The failure rate per component per unit of time is best described as an illustration. The NIIN 01-278-9291 is selected, which has a failure rate per component per unit of time of .0042. It is obtained with two simple steps.

The first step is to divide the total amount of site repairs which occurred over 180 days, by 180 days (total amount of site repairs which occurred in 180 days / by the same amount of days in which the site repairs occurred which would be 180 days). The NIIN 01-278-9291 features 18 site repairs within a period of 180 days (see Table 4.2). The 180 days are divided into the 18 days of site repairs to obtain the failure rate per component (18 / 180 = .1).

The second step is to divide the failure rate per component for one aircraft into the number of aircraft in the system, which is 24, to obtain the failure rate per component for 24 aircraft (.1 / 24 = .0042).

The service rate per channel per unit of time is defined as the actual rate of repair by AIMD measured in days. Table 4.2 provides the repair times furnished by NALDA. The repair time is defined as the time in days in took AIMD to repair the Non-RFI into a serviceable RFI. It does not include AWP. The service rate per channel per unit of time is obtained by dividing one by the time of repair. Utilizing NIIN 01-278-

9291 as an example, 1 / 3.6 = a service rate of .2778, or the service rate could be described at a rate of 1/ 3.6 repairs per day.

The NIIN 01-278-9291 featured a 90 day allowance of four spares and a 60 day allowance of three spares (see Table 3.1). The following sample input and output of the finite source queueing model (Gross and Harris, 1985) as executed by the RP-FOR model (of NIIN 01-278-9291) is provided in Figures 4(B) and 4(C).

90 DAY ALLOWANCE INPUT

Number of aircraft	24.
Number of repair channels	1.
Number of spares	4.
Failure rate per component per unit time	.004
Service rate per channel per unit time	.278

90 DAY ALLOWANCE OUTPUT

Probability of stockout	.00608
Avg number of spares in the AIMD	.56799
Avg number of spares in the repair queue	.20527
Avg number of ACs grounded	.00911
Turn-around-time (TAT)	5.63691
Operational Availability of ACs	.99962

Figure 4(B)--Sample Input / Output of RP-FOR MODEL for 90 Day AVCAL

60 DAY ALLOWANCE INPUT

Number of aircraft	24.
Number of repair channels	1.
Number of spares	3.
Failure rate per component per unit time	.004
Service rate per channel per unit time	.278

60 DAY ALLOWANCE OUTPUT

Probability of stockout	.01675
Avg number of spares in the AIMD	.56593
Avg number of spares in the repair queue	.20346
Avg number of ACs grounded	.02511
Turn-around-time (TAT)	5.62031
Operational Availability of ACs	.99895

Figure 4(C)--Sample Input / Output of RP-FOR MODEL for 60 Day AVCAL

TABLE 4.2--DATA INPUT FOR THE RP-FOR MODEL

NIIN	# OF SITE REPAIRS 180 DAYS	FAILURE RATE PER COMPONENT FOR 24 AC	FAILURE RATE PER COMPONENT FOR 1 AC	DAYS OF REPAIR	SERVICE RATE PER DAY
01-093-1491	13	.0722	.0030	2.9	.3448
01-119-0647	28	.1555	.0065	3.6	.2778
01-123-2204	75	.4167	.0173	0.4	2.5000
01-129-3954	7	.0389	.0016	1.4	.7143
01-131-8104	13	.0722	.0030	0.4	2.5000
01-144-0132	5	.0278	.0012	4.0	.2500
01-156-7310	37	.2056	.0086	2.0	.5000
01-158-9694	9	.0500	.0021	11.3	.0885
01-163-6062	44	.2444	.0102	0.1	10.0000
01-201-3256	29	.1611	.0067	0.8	1.2500
01-220-4768	6	.0333	.0014	4.1	.2439
01-232-8815	40	.2222	.0093	0.1	100.0000
01-240-5562	59	.3278	.0137	1.1	.9091
01-247-5025	39	.2167	.0090	2.8	.3571
01-271-4573	74	.4111	.0172	1.9	.5263
01-278-9291	18	.1000	.0042	3.6	.2778

TABLE 4.3--RP-FOR OPERATIONAL AVAILABILITY RESULTS

NIIN	90 DAY ALLOW	OPERATIONAL AVAILABILITY	60 DAY ALLOW	OPERATIONAL AVAILABILITY
01-093-1491	3	.9999	2	.9995
01-119-0647	3	.9930	2	.9873
01-123-2204	42	1.0000	30	1.0000
01-129-3954	2	.9999	1	.9999
01-131-8104	3	1.0000	2	1.0000
01-144-0132	1	.9995	0	.9951
01-156-7310	3	.9982	2	.9956
01-158-9694	3	.9920	2	.9858
01-163-6062	7	1.0000	5	1.0000
01-201-3256	3	1.0000	2	1.0000
01-220-4768	6	1.0000	5	1.0000
01-232-8815	14	1.0000	10	1.0000
01-240-5562	3	.9989	2	.9970
01-247-5025	3	.9894	2	.9823
01-271-4573	6	.9847	5	.9800
01-278-9291	4	.9996	3	.9990

The RP-FOR model results from Table 4.3 display the loss of operational availability of the aircraft due to the 30 day reduction of the items. Using NIIN 01-278-9291 as an example, operational availability decreased from 99.96 to 99.90 percent (equivalent of four aircraft out of 1,000 being grounded compared to 10 aircraft out of 1,000 being grounded), i.e., a 30 day AVCAL reduction of NIIN 01-278-9291 would cause an average of .06 less aircraft available out of 100 aircraft. The RP-FOR model calculates operational availabilities under the assumption that all other RP or components are perfect (without failure). The operational availability from this model may be higher than reality because of the distributional assumptions required in the finite source queueing model. For this particular NIIN (01-278-9291), the savings of the reduction of AVCAL from 90 to 60 days would be the standard unit price of $23,300.00.

In order for the RP-FOR model to properly execute the finite source queueing model, the following assumptions were made:

- It is assumed that each item's failure is statistically independent of the other item's failures. Once failed, it is also assumed that each item has its own single repair channel.
- The only items considered were *USS Independence* RP F/A-18 items which suffered from an attritional loss due to a reduction of AVCAL from 90 to 60 days.
- Both service time and time between failures are assumed to follow exponential distribution.
- BCM's were not considered.

Although the RP-FOR model does not consider the BCM aspect and does make some significant assumptions, it does provide a quick and easy procedure for decision makers to make a sensitivity analysis.

B. RP-SIM MODEL

1. Input Requirements

The pitfalls of the RP-FOR model assumptions require more than just an analytical model. According to Griffin (1978), simulation has the capability to overcome any shortcomings of formal means of analysis:

> Computer simulation is a very powerful tool. When properly utilized it can be used to develop insights into very complex queueing systems which seem to defy more formal means of analysis. The advantage of which simulation has over more formal analysis is that it often has a higher degree of isomorphism with the relative phenomena it represents.

A simulation model written in SIMAN simulation language (Pegden, C.D. et. al., 1991) was developed to investigate any possible loss of operational availability due to the 30 day AVCAL reduction. It was designed to accurately simulate the RP, including the BCM actions and the arrival of the BCM replacements.

The model consists of two parts; the first part is the model frame which includes the basic block functions of the simulation desired. The second part is the experimental frame which consists of specifications of the experimental conditions for executing the model.

The system model incorporates the following procedures:

- Arrival of entities to the system, including group arrivals to occur with the group size, number of groups and arrival pattern.

- Assignment of a value to an attribute in order to provide the value an expression to the attributes of the entity.

- Entity delays can be incorporated to account for any activity which consumes time. Each delay results in a queue, which can be assigned a particular capacity or balking option.

- A register which maintains statistics on the mean, variance, minimum, and number of observations.

- Resource units are incorporated to account for any inventory spares. Resource capacity, the number of units required, and a priority number to be used for allocation.

- A release procedure to make available any idle resource units when they are requested.

- A branch process is incorporated to facilitate the control of probabilistic or conditional entity flow over a set of one or more branches.

The experimental frame allows the construction of specific conditions for a simulation of the model. The experimental frame provides the following procedures:

- The ability to implement the SIMAN Summary Report, which is a statistical summary of the simulation response for each run and is automatically generated by the run processor if selected.

- The specification of resources to be used in the model, including the resource capacity.

- The ability to obtain time-persistent statistics on variables for example resource utilization or average number of spare parts waiting to be repaired.

The SIMAN Summary Report provides any required information and any requested time-persistent statistics. A listing of the RP-SIM model is provided in Appendix C. It includes the model frame and the experimental frame using the NIIN 01-278-9291 as an example.

2. RP-SIM model data input

The system model and experimental frame require the following data (listed in Table 4.4, which was obtained from NALDA, FASOINST 4441.15F, and 90 and 60 day AVCAL computations) in order to execute a logical and realistic simulation:

- Time between failures, which is defined as the time (in days) between the arrivals of Non-RFI items for repair. It is assumed to be exponentially distributed. The time between failures is calculated by dividing the number of site repairs into the amount of days the site repairs occurred. An example would be the NIIN 01-278-9291 which features 18 site repairs within a period of 180 days (see Table 4.2). The 18 site repairs are divided into the 180 days used in the specified period to obtain the time between failures of 10 days (180 days / 18 site repairs = 10 days).

- Two different distributions are used for delay times to see the effects of distribution assumptions. The mean value of exponential distribution and normal distribution was obtained from NALDA and the standard deviation of the normal distribution was assumed to be 10 percent of the mean value.

- BCM rate, which is defined as the probability of an item being BCM'd. In order to properly execute in the RP-SIM model, the BCM rate provided from NALDA (see Table 4.4) is divided by 100. An example would be NIIN 01-278-9291. It has a BCM rate (defined by NALDA as the number of BCMs divided by the total sum of the amount of BCMs and RFIs) of 15.8, which would be divided by 100 (15.8 / 100 = .158) to obtain the BCM probability of .158 for the RP-SIM model.

- Delay time incurred due to removal and installation of the item is the unconstrained removal and process time in days to account for the time to install the RFI part into the aircraft.

- AWP and Repair time, which account for the AIMD delay time in obtaining the required parts for repair and the actual repair time of fixing the Non-RFI component.

- O&ST for BCM replacements for a deployed CV in the Indian Ocean based upon personal experience, using a triangular distribution of a best case scenario of receipt in five days, average receipt time of 15 days and a worst case scenario of receipt in 30 days.

- AVCAL quantity, derived from computations.

Table 4.4 provides a listing by NIIN of the applicable data entries into the RP-SIM model. The allowance quantities are in units, the BCM rate is a percentage, and the remaining data is in days. The data from NALDA consist of the time between failures, the BCM rate, removal and schedule times, and AWP and repair times. The 90

and 60 day AVCAL quantities were computed based upon the modeling describe in Chapter III. Table 4.5 is a sample output from the RP-SIM model using NIIN 01-093-1491 with a 90 day allowance of three spares and an exponentially distributed failure time.

TABLE 4.4--RP-SIM MODEL INPUT VARIABLES WITH 90 AND 60 DAY ALLOWANCES

NIIN	TIME BTWN FAILURES (DAYS)	BCM RATE %	REMOVAL & SCHEDULE (DAYS)	AWP & REPAIR (DAYS)	90 DAY ALLOW (ITEMS)	60 DAY ALLOW (ITEMS)
01-093-1491	13.85	16.7	.4	7.0	3	2
01-119-0647	6.43	8.0	3.3	8.2	3	2
01-123-2204	2.40	95.9	0.4	0.4	42	30
01-129-3954	25.77	50.0	0.4	2.5	2	1
01-131-8104	13.85	38.5	2.1	0.4	3	2
01-144-0132	36.00	40.0	0.8	15.4	1	0
01-156-7310	4.87	5.4	0.8	9.3	3	2
01-158-9694	20.00	50.0	0.5	15.6	3	2
01-163-6062	4.09	27.3	0.6	1.4	7	5
01-201-3256	6.21	10.7	0.6	2.5	3	2
01-220-4768	30.00	77.8	1.1	17.0	6	5
01-232-8815	4.50	92.3	2.6	0.1	14	10
01-240-5562	3.05	3.3	0.3	1.8	3	2
01-247-5025	4.62	5.3	0.9	7.5	3	2
01-271-4573	2.43	4.2	1.4	5.1	6	5
01-278-9291	10.00	15.8	0.5	9.3	4	3

TABLE 4.5--EXAMPLE OF RP-SIM MODEL SUMMARY REPORT

SIMAN IV - License #9050352
Naval Postgraduate School

Summary for Replication 1 of 2

Project: REPAIR — Run execution date: 10/13/1991
Analyst: G.LEOPARD — Model revision date: 10/13/1991
Replication ended at time: 1095.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
TIME IN SYSTEM	.94202	.90604	.68542E-01	6.88430	83
RP TAT	7.49520	.82399	.29535	24.37300	70
SPARE TAT WITH BCM	16.97400	.30827	8.86820	24.33600	13

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
AWAIT INSTALLATION	.00586	13.02900	.00000	1.00000	.00000
RFI ITEM INSTALLATION	.63981	1.25240	.00000	3.00000	.00000

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Summary for Replication 2 of 2

Project: Repair — Run execution date: 10/13/1991
Analyst: G.LEOPARD — Model revision date: 10/13/1991
Replication ended at time: 2190.0
Statistics were cleared at time: 1095.0
Statistics accumulated for time: 1095.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
TIME IN SYSTEM	.88494	.78548	.59570E-01	3.35140	83
RP TAT	6.09610	.95240	.33643	29.26000	64
SPARE TAT WITH BCM	18.97200	.22281	9.68510	25.09800	17

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
AWAIT INSTALLATION	.00326	20.69000	.00000	2.00000	.00000
RFI ITEM INSTALLATION	.63468	1.20590	.00000	3.00000	2.00000

Run Time: 0 min(s) 14 sec(s)

The key indicator from the RP-SIM Summary Report for this particular program are the results of Identifier AWAIT INSTALLATION, which represents the mean number (average) of aircraft grounded during the period of the simulation (the example of RP-SIM model displayed in Table 4.5 represents a period of three years) due to a lack of RFI part availability to replace the Non-RFI part which was removed. The Await Installation Identifier is located in the DISCRETE-CHANGE VARIABLES section of the SIMAN Summary Report (see Table 4.5). The Await Installation Identifier consists of five categories with units expressed in days. The categories are as follows:

- Average, which represents the mean average number of aircraft grounded during the time period of the simulation due to a lack of RFI part availability to replace the Non-RFI part which was removed from the end item.
- Minimum (maximum), which represents the minimum (maximum) number of aircraft which were grounded at any particular time during the period of the simulation due to a lack of RFI part availability.
- Variation represents the variance of the observations.
- Final Value, which represents the amount of aircraft which were grounded due to a lack of RFI parts availability when the simulation was completed.

The replicate element in the experimental frame required two computer simulation runs. Each run was for three consecutive years. The NO option was specified, which meant the system status was not re-initialized to their original state at the beginning of the run. The purpose not to re-initialize the second run was to reduce the initial transient bias of the start up. The average amount of time the aircraft was grounded due to the lack of availability of the component was selected from the second

run, which represented years four through six. It was assumed that the system would be operating at a steady state during those years.

A total of four sets of RP-SIM simulation runs were conducted with each of the 16 NIINs. Two variables were involved; the amount of days of allowance (90 and 60) and the delay times (exponential and normal distribution). A pair of RP-SIM simulation runs were conducted for a 90 day allowance using exponential delay times and for normal delay times. Likewise, a pair of RP-SIM simulation runs were conducted for a 60 day allowance using exponential and normal delay times. This procedure obtained the average amount of time the aircraft was grounded due to the lack of availability of the item of each NIIN with both a 90 and 60 day AVCAL, using both the normal and exponential delay times. Normal distribution provides a standard deviation of 10 percent of the average mean. Thus, its variance of occurrence is smaller than exponential distribution. The data available from NALDA was restricted in the sense it did not provide any distribution data. This thesis examined both distributions, exponential and normal with all associated delay times. However, the time between failures was assumed to be exponential.

Table 4.6 provides the results of the values, listing the average number of aircraft grounded with 90 and 60 day allowances using normal and exponential delay times.

TABLE 4.6--RP-SIM MODEL SUMMARY REPORTS OF AVERAGE NUMBER OF AIRCRAFT GROUNDED WITH 90 AND 60 DAY ALLOWANCES USING NORMAL AND EXPONENTIAL DELAY TIMES

NIIN	90 DAY ALLOW	NORMAL	EXPO	60 DAY ALLOW	NORMAL	EXPO
01-093-1491	3	.0045	.0033	2	.0319	.0191
01-119-0647	3	.0519	.1813	2	.2311	.3090
01-123-2204	42	.0000	.0000	30	.0000	.0000
01-129-3954	2	.0048	.0028	1	.0483	.0455
01-131-8104	3	.0051	.0000	2	.0191	.0001
01-144-0132	1	.1325	.0993	0	.1850	.1530
01-156-7310	3	.1761	.1897	2	.5367	.4853
01-158-9694	3	.0109	.0036	2	.0281	.0200
01-163-6062	7	.0000	.0000	5	.0000	.0000
01-201-3256	3	.0033	.0001	2	.0283	.0334
01-220-4768	6	.0000	.0000	5	.0000	.0000
01-232-8815	14	.0000	.0000	10	.0000	.0000
01-240-5562	3	.0029	.0068	2	.0417	.0494
01-247-5025	3	.1058	.1732	2	.4170	.5485
01-271-4573	6	.0064	.0108	5	.0438	.0374
01-278-9291	4	.0088	.0045	3	.0319	.0174

The total number of F/A-18 Hornets assigned to *USS Independence* is 24, representing two squadrons of 12 aircraft each. By using the data from the RP-SIM model Summary Report, specifically the Identifier Await Installation times under the category of average, the $A_o(i)$ can be computed for both the 90 and 60 day AVCAL. An example of the $A_o(i)$ computation of NIIN 01-278-9291 is provided. Utilizing the average number of aircraft grounded with normally distributed delay times generated by the RP-SIM model and listed in Table 4.6 (.0088) results with an operational availability of .9996 ($A_o(i) = (24 - .0088) / 24 = .9996$).

The $A_o(i)$ results listed by NIIN (using exponential failure time with both normal and exponential delay times) for 90 and 60 days of AVCAL, computed from the data derived from the RP-SIM Summary Report, are provided in Table 4.7.

Compared to the RP-FOR model results in Table 4.3, the operational availability calculated from simulation are generally lower. It is probably due to the BCM action which the RP-SIM model takes into account.

TABLE 4.7--RP-SIM MODEL ITEM OPERATIONAL AVAILABILITY RESULTS WITH 90 AND 60 DAY ALLOWANCES UNDER NORMAL AND EXPONENTIAL DELAY TIMES

NIIN	90 DAY ALLOW	NORMAL	EXPO	60 DAY ALLOW	NORMAL	EXPO
01-093-1491	3	.9998	.9998	2	.9986	.9992
01-119-0647	3	.9978	.9924	2	.9903	.9871
01-123-2204	42	1.0000	1.0000	30	1.0000	1.0000
01-129-3954	2	.9997	.9998	1	.9980	.9981
01-131-8104	3	.9997	1.0000	2	.9992	.9999
01-144-0132	1	.9944	.9959	0	.9923	.9936
01-156-7310	3	.9927	.9921	2	.9776	.9798
01-158-9694	3	.9995	.9998	2	.9988	.9992
01-163-6062	7	.9999	1.0000	5	1.0000	1.0000
01-201-3256	3	.9999	.9999	2	.9988	.9986
01-220-4768	6	1.0000	1.0000	5	1.0000	1.0000
01-232-8815	14	1.0000	1.0000	10	1.0000	1.0000
01-240-5562	3	.9999	.9997	2	.9980	.9980
01-247-5025	3	.9956	.9928	2	.9826	.9772
01-271-4573	6	.9998	.9995	5	.9982	.9985
01-278-9291	4	.9996	.9998	3	.9987	.9993

$A_o(rp)$ consists of all of the RP items with an IMEC of a critical nature (the IMEC of the item signifies the aircraft will be grounded or its mission curtailed if the item is not working and no replacements are readily available). If the $A_o(i)$ of each item decreases, then the $A_o(rp)$ will also decrease as a total product of every critical item's A_o.

To obtain the $A_o(rp)$ of the F/A-18 Hornet RP items affected by attrition due to a reduction of AVCAL from 90 to 60 days, each of the 16 NIIN's $A_o(i)$'s as listed in Table 4.7 were multiplied against each other to obtain the system availability of the F/A-18 Hornet, i.e.;

$$A_o(system) = \prod_{i=1}^{16} A_o(i)$$

This assumes that all failures occur independent of each other. Table 4.8 provides the $A_o(rp)$ which were produced and clearly demonstrates that although the $A_o(i)$ on an independent basis did not change in any significant amount with the reduction of AVCAL from 90 to 60 days (see Table 4.7), the $A_o(rp)$ of the F/A-18 Hornet RP (consisting of the 16 *USS Independence* RP NIIN's which suffered an attritional loss of allowance due to the reduction of AVCAL from 90 to 60 days) did change in a very significant manner. However, the difference in time distribution does not make significant impact on the operational availability.

Using normally distributed delay times, the $A_o(rp)$ decreased from 97.85 percent to 93.30 percent (see Table 4.8), which can be translated into grounded aircraft. From a pool of 100 aircraft, the average number of grounded aircraft went from 2.15 to 6.70.

Using an exponentially distributed delay times, the F/A-18 Hornet RP operational availability decreased from 97.18 percent to 93.05 percent (see Table 4.8). Accordingly, the average number of grounded aircraft of the pool of 100 went from 2.82 to 6.95.

TABLE 4.8--F/A-18 HORNET RP OPERATIONAL AVAILABILITIES, $A_o(rp)$

	90 Day AVCAL	60 Day AVCAL
Normally distributed delay times	.9785	.9330
Exponentially distributed delay times	.9718	.9305

V. SUMMARY AND CONCLUSIONS

A. SUMMARY

The driving force of this thesis was to provide decision makers with a logical and realistic model (the AVCAL Reduction Analysis model utilizing either the RP-FOR or RP-SIM models, or both) to properly assess the impact of reducing a CV's AVCAL. The model would provide the benefits in dollars saved with the reduction of AVCAL matched against the penalties of reduced operational availability of the aircraft is based upon two key factors. First, the availability, or lack of, of the component in the rotatable pool (defined as $A_o(i)$), and secondly, the percent of time the aircraft is operational due to the availability of the 16 F/A-18 Hornet spares in the RP (defined as $A_o(rp)$). Additionally, in order to facilitate easy use, the model had to be user-friendly.

Although this thesis examined the reduction of a CV's AVCAL from 90 to 60 days, the model's flexibility allows decision makers to reduce or increase a CV's AVCAL to any limit, and still be capable of providing the costs and benefits of any such AVCAL alteration.

Most importantly, if indeed, the new War Material Stockage Policy of maintaining enough war material on hand for forward deployed units to sustain wartime operations for 60 days is accepted, then this model will be readily available for quick and easy implementation and use. And the model's flexibility allows the decision makers to increase or decrease the amount of scope and assumptions they desire to use. The model

can be easily modified to include only Aviation Depot Level Repairables (AVDLRs) (ignore the computations of the Raw LRCR quantities if no field level repair is possible) or remain untouched (compute the Raw LRCR quantities and the Raw attrition quantities) to model selected field level repairables for a cost and benefit analysis. (For example, reviewing the cost and benefits of field level repairables with various IMEC codes. Items with no significant IMEC can have their AVCAL quantity reduced with minimal impact based upon the $A_o(i)$, and no direct impact on the system availability of the aircraft.) The model demonstrated the flexibility for decision makers to use different distributions for delay times. The analysis of the results showed that in most cases, the failure times of both exponential and normal produced very little differences.

B. CONCLUSIONS

In analyzing RP-SIM results, several NIINs did not suffer a reduced $A_o(i)$ with an allowance reduction. The NIINs which did not suffer a drop in $A_o(i)$ generally had a large allowance (six or more) as the AVCAL was reduced from 90 to 60 days. Those items are outstanding examples of NIINs which feature a definite savings benefit with no anticipated costs (either with a loss of $A_o(i)$, or $A_o(rp)$) with an AVCAL reduction. However, as the allowance became smaller, the $A_o(i)$ impact (and thus the impact upon $A_o(rp)$) with the reduction in AVCAL became more significant. Those particular NIINs clearly demonstrated much higher costs with a more pronounced reduction of $A_o(i)$ as the AVCAL was reduced by 30 days. Decision makers need to pay closer attention in

examining the costs and benefits of reducing AVCAL of NIINs with a small (two or less) allowance.

However, for AVDLRs which show little or no demand history and are only being carried in the AVCAL because of their IMEC and not because of their demand, a cost and benefit analysis using this model may be very useful. The fact that these items record little or no demand signifies they experience very few, if any, failures. With such a low amount of failures, a reduction of their allowance may result in little to no change of the item's $A_o(i)$ (and thus little or no impact upon the $A_o(rp)$). Those items, due to little or no demand, may warrant removal from the AVCAL and be consolidated at a forward deployed site to reduce O&ST (reducing the amount of time the aircraft may be grounded and thus assist in maintaining a high $A_o(i)$, and $A_o(rp)$ when and if a demand does occur.

A strong assumption used in the RP-SIM simulation model is the assumption that all failures are independent of each other. The independent failure of an item without a readily available replacement (RFI spare) will ground the aircraft for a certain period of time until a RFI part is issued. Table 4.7 lists the $A_o(i)$ of the F/A-18 RP items onboard *USS Independence* which suffered from an attritional loss of spares as the AVCAL was reduced from 90 to 60 days. In almost every case, if the item suffered an allowance loss due to the reduction of AVCAL from 90 to 60 days, it also suffered an $A_o(i)$ loss. The

Although the loss of A_o was minimal, its impact upon the $A_o(rp)$ was significant and a considerable loss of $A_o(rp)$ as highlighted in Table 4.8 did occur. This analysis is very important for any decision makers considering the reduction of AVCAL. Not only must the decision makers consider the cost of an AVCAL reduction in terms of $A_o(i)$,

they must also consider the impact upon $A_o(rp)$. An AVCAL reduction from 90 to 60 days affecting the F/A-18 RP items with a critical IMEC would result in very small $A_o(i)$, but with significant loss of F/A-18 Hornet $A_o(rp)$.

The decision maker must weigh the dollar savings gained from an AVCAL reduction against the loss of F/A-18 $A_o(rp)$. Table 3.1 shows the approximate savings of $1,295,633.00 of F/A-18 Hornet RP items with an AVCAL reduction from 90 to 60 days. The penalty of such savings was documented in the decrease of $A_o(i)$ (see Table 4.7) and the corresponding drop in $A_o(rp)$ (see Table 4.8).

While the AVCAL reduction will save money by reducing the amount of stock onboard ship, decision makers need to be aware of the possible ramifications of an AVCAL reduction and the increase of financial requirements elsewhere in the system.

One of the impacts of possibly reducing a CV's AVCAL will be the increased importance and value of the logistics pipeline. Greater significance will be placed upon expediting action, maintaining real time status of the reorders, and air shipment of critical NMCS/PMCS requisitions.

Likewise, a reduction of AVCAL will save the USN money by reducing the amount of stock onboard ship, but it will also lower the expectations of senior DoD officials in a proportionate amount with regards to aviation support excellence and the maintenance of high PMC and FMC rates.

Additionally, the reduction of AVCAL onboard the CVs and the possible elimination of intermediate level stock within the supply system will place greater emphasis on the efficiency of the aviation depots. The depots will be tasked to provide

real time status of every inducted Non-RFI repairable and will be expected to provide quick and prompt repair. These expectations will no doubt result in demands by the depots for a larger operating budget--A very challenging demand in light of the rapidly shrinking DoD budget.

The increase of importance of the logistics pipeline, and of TAT by the depots may require additional funding which may or may not exceed the savings of the AVCAL reductions from the CVs.

Another aspect decision makers must take into account with a CV AVCAL reduction is the risk they are taking of the logistics pipeline remaining open during a war. A reduction of AVCAL depth will place greater reliance on the efficiency of the logistical pipeline. The decision makers face a horrifying dilemma if the pipeline is interrupted or cut. Decision makers must weigh the risk of the possibility of such an event occurring, although their is currently a perceived diminished threat of the Soviet Union and DoD is expecting only regional contingencies to occur. Decision makers need to evaluate that risk and determine how best to handle the risk prior to making any significant change in a CV's AVCAL.

However, and most importantly, this thesis emphasizes the importance decision makers must place on $A_o(rp)$, which is a direct result of the reduction of $A_o(i)$, when measuring the cost and benefits of reducing an AVCAL. Decision makers must not overlook the small incremental loss of $A_o(i)$ with a reduction of AVCAL. They must also consider the impact of the degradation the $A_o(i)$ will have on $A_o(rp)$. The reduction of the AVCAL has a ripple affect throughout the aviation support community. At first

glance, an AVCAL reduction of 30 days from 90 to 60 appears to provide significant cost savings with little or no impact upon $A_o(i)$. If taken one step further, it is noted that the F/A-18 Hornet's $A_o(rp)$ will decrease as a product of the total decrease of all of the $A_o(i)$.

Although a reduction of $A_o(i)$ within the CV's RP will cause a direct impact upon the CV's $A_o(rp)$ of that particular aircraft affected, this model does not provide the process to ascertain the impact a reduction of AVCAL will make upon the overall system operational availability of the aircraft. Too many variables (including the RP items, AVDLRs, consumable support, engine support, interim support, efficiency of the aviation support triad) are involved for this model to properly ascertain the affect an AVCAL reduction would make upon the overall aircraft operational availability.

However, if and when any decision makers will need to analyze the impact of an AVCAL reduction, the AVCAL Reduction Analysis model will properly assist them in weighing the full benefits and penalties of any such reduction. The RP-FOR model will provide decision makers the means for a quick and dirty analysis and the RP-SIM model will provide them a more specific and comprehensive analysis.

APPENDIX A

The F/A-18 Rotatable Pool items onboard *USS Independence* as of 05 August 1991 are listed below in NIIN sequence. The applicable NALDA AV-3M data input requirements were used to compute the theoretical 90 and 60 day allowances. Items which did not have any AV-3M data are noted with NA. Those items do not have any AV-3M data for several reasons. Principally, because they may have been included into the Rotatable Pool after the deployment which was the period of time the AV-3M data used in the computations covered, they may not have generated any data during the deployment, or the data generated may have been input into the AV-3M system incorrectly. Items which suffered from an attritional loss of allowance are listed in **Bold face**.

	90 DAY ALLOWANCES			60 DAY ALLOWANCES		
NIIN	ATTRITION	LRCR	TOTAL	ATTRITION	LRCR	TOTAL
01-091-2434	0	0	0	0	0	0
01-093-1491	**1**	**2**	**3**	**0**	**2**	**2**
01-119-0647	**1**	**2**	**3**	**0**	**2**	**2**
01-119-9585	0	0	0	0	0	0
01-123-2204	**42**	**0**	**42**	**30**	**0**	**30**
01-127-8779	NA					
01-129-3954	**2**	**0**	**2**	**1**	**0**	**1**

NIIN	90 DAY ALLOWANCE ATTRITION	LRCR	TOTAL	60 DAY ALLOWANCE ATTRITION	LRCR	TOTAL
01-131-8104	**3**	**0**	**3**	**2**	**0**	**2**
01-139-5544	NA					
01-144-0132	**1**	**0**	**1**	**0**	**0**	**0**
01-145-2755	NA					
01-148-1566	NA					
01-150-6560	0	0	0	0	0	0
01-151-0750	0	0	0	0	0	0
01-151-2889	NA					
01-151-2890	NA					
01-152-0880	0	0	0	0	0	0
01-152-6034	0	0	0	0	0	0
01-156-0814	NA					
01-156-7310	**1**	**2**	**3**	**0**	**2**	**2**
01-158-9694	**3**	**0**	**3**	**2**	**0**	**2**
01-159-6944	0	4	4	0	4	4
01-162-9314	0	0	0	0	0	0
01-163-6062	**7**	**0**	**7**	**5**	**0**	**5**
01-177-4925	NA					
01-179-4064	0	1	1	0	1	1
01-201-3256	**2**	**1**	**3**	**1**	**1**	**2**

	90 DAY ALLOWANCE			60 DAY ALLOWANCE		
NIIN	ATTRITION	LRCR	TOTAL	ATTRITION	LRCR	TOTAL
01-203-3480	0	3	3	0	3	3
01-216-7931	0	1	1	0	1	1
01-216-8124	0	2	2	0	2	2
01-220-4768	**4**	**2**	**6**	**3**	**2**	**5**
01-222-0088	NA					
01-226-8646	0	3	3	0	3	3
01-232-8815	**14**	**0**	**14**	**10**	**0**	**10**
01-240-5562	**1**	**2**	**3**	**0**	**2**	**2**
01-242-9763	NA					
01-245-1986	NA					
01-247-5025	**1**	**2**	**3**	**0**	**2**	**2**
01-265-3659	NA					
01-265-3660	0	0	0	0	0	0
01-271-4424	0	0	0	0	0	0
01-271-4573	**2**	**4**	**6**	**1**	**4**	**5**
01-278-3548	0	1	1	0	1	1
01-278-9291	**2**	**2**	**4**	**1**	**2**	**3**
01-291-7577	NA					
01-315-9389	NA					
01-324-3924	NA					

APPENDIX B

A listing of the RP-FOR model to calculate the probability of stockout, average number of spares within AIMD, average number of spares in the repair queue, average number of aircraft grounded during the time period of the model, TAT and operational availability of aircraft is provided below. A copy of this program may be obtained from the author, or Professor Keebom Kang of Naval Postgraduate School, Monterey, CA. See the distribution list for contact.

The program, written in FORTRAN is based on the finite source queueing model discussed in Gross and Harris (1985). It provides a very quick, simple and easy method to calculate the items listed above and is a recommended tool for decision makers to use as a quick snap-shot to analyze the costs and benefits of an AVCAL reduction.

```
c
      implicit double precision (a-h,o-z)
      dimension c(100), p(0:100)
c
c
      open(10,file='spare.out',status='old')
      print *, "How many aircraft?"
      read *, aircraft
      print *, "How many spares?"
      read *, spare
      print *, "What is the failure rate?"
      read *, xlambda
      print *, "What is service rate?"
      read *, xmu
      print *, "How many repair channels?"
      read *, channel
      rho=xlambda/xmu
c
      prod = rho
      sum=0.
c
      factac = fact(aircraft)
```

```
c
c       if the # of channels > # of spares
c
        if (channel .gt. spare) then
c
        do 10 n = 1,spare+aircraft
c
        if(n.le.spare) then
        temp = n
        c(n) = prod * aircraft**n / fact(temp)
c
        elseif (n.le.channel) then
c
        temp = n
        temp1 = prod * aircraft**spare /fact(temp)
        temp2 = factac / fact(aircraft+spare-n)
        c(n) = temp1 * temp2
c
        else
c
        temp1 = prod * aircraft**spare
        temp1 = temp1 / fact(channel) / (channel**(n-channel))
        temp2 = factac / fact(aircraft+spare-n)
        c(n) = temp1 * temp2
c
        endif

        prod = prod*rho
        sum = sum + c(n)
10         continue
c
        else
c
c       if # of channels <=  # of spares
c
c
        do 20 n = 1,spare+aircraft
c
        if(n.le.channel) then
c
        temp = n
        c(n) = prod * aircraft**n / fact(temp)
c
        elseif (n.le.spare) then
c
        c(n) = prod * aircraft**n / fact(channel) /
        &                 (channel**(n-channel))
c
        else
c
        temp1 = prod * aircraft**spare
        temp1 = temp1 / fact(channel) / (channel**(n-channel))
        temp2 = factac / fact(aircraft+spare-n)
        c(n) = temp1 * temp2
c
        endif
c
        prod = prod*rho
        sum = sum + c(n)
20         continue
```

```
c
c
      endif
c
      p(0) = 1./(1.+sum)
c
      xnumsys = 0.
      xnumque = 0.
      xnumgrd = 0.
      stockout = 0.
c
      do 40 n = 1, spare+aircraft
      p(n) = c(n) * p(0)
      xnumsys = xnumsys + n*p(n)
      if (n.gt. channel)xnumque = xnumque + (n-channel)*p(n)
      if(n.gt.spare) then
      xnumgrd = xnumgrd + (n-spare)* p(n)
      stockout = stockout + p(n)
      endif
40    continue
c
c     calculate of operational availability of AC
c
      operav = (aircraft - xnumgrd)/ aircraft
c
c     Turn-around-time (TAT) calculation using Little's Law
      xlambef = xlambda * (aircraft - xnumgrd)
      tat =  xnumsys / xlambef
c
c     REPORT GENERATOR
c
      write(*,101) aircraft, channel, spare, xlambda, xmu
      write(10,101) aircraft, channel, spare, xlambda, xmu
c
101   format(///1x,'Number of aircraft                        ', f8.0,
     &         /1x,'Number of repair channels                 ', f8.0,
     &         /1x,'Number of spares                          ', f8.0,
     &         /1x,'Failure rate per component per unit time', f8.3,
     &         /1x,'Service rate per channel per unit time  ', f8.3)
c
c
      write (*,102) stockout, xnumsys, xnumque, xnumgrd, tat, operav
      write (10,102) stockout, xnumsys, xnumque, xnumgrd, tat, operav
102   format( /1x,'Probability of stockout                   ', f10.5,
     &         /1x,'Avg number of spares in the AIMD        ', f10.5,
     &         /1x,'Avg number of spares in the repair queue', f10.5,
     &         /1x,'Avg number of ACs grounded              ', f10.5,
     &         /1x,'Turn-around-time (TAT)                  ', f10.5,
     &         /1x,'Operational Availability of ACs         ', f10.5/)
c
      stop
      end
c
      double precision function fact(x)
      implicit double precision (a-h,o-z)
      prod = 1.d0
      do 10 i = 1, x
      prod = prod * i
10    continue
      fact = prod
```

```
return
end
```

APPENDIX C

The RP-SIM Simulation model program is provided below.

```
BEGIN,Y, REPAIR;
;
;         LT GUY L. LEOPARD, SC, USN
;         01 DECEMBER, 1991
;
;        SIMULATION MODEL OF ROTATABLE POOL AND BCM ACTION TO OBTAIN LOSS
;         OF OPERATIONAL AVAILABILITY DUE TO SMALLER ROTATABLE POOL
;         ALLOWANCE DERIVED FROM FORMULAS LISTED IN FASOINST 4441.15F
;
          CREATE:EXPO(10);          TIME BETWEEN FAILURES
          ASSIGN:TimeIn=TNOW;       START TAT
;
          DELAY:EXPO(.5);           REMOVAL & PROCESS TIME
;
          BRANCH,2:
             ALWAYS,ACFT:
             ALWAYS,BOX;            SEPARATE NRFI BOX FROM ACFT
;
;         ROTATABLE POOL QUEUE
;
     ACFT QUEUE,SPAREQ;             RFI SPARE TO INSTALL INTO ACFT
          SEIZE:SPARE;              RFI ISSUE FROM ROTATABLE POOL
          DELAY:EXPO(.5);           INSTALL TIME SAME AS REMOVAL TIME
          TALLY:TIME IN SYSTEM,INT(TimeIn):DISPOSE;
;
     BOX  BRANCH,1:
             WITH,.158,BCM:
             ELSE,AIMD;             BCM PROBABILITY
;
;         AIMD REPAIR
;
     AIMD DELAY:EXPO(9.2);          AWP & REPAIR TIME
          TALLY:RP TAT,INT(TimeIn);
          RELEASE:SPARE:DISPOSE;    RELEASE RFI SPARE TO RP
;
;         BCM ORDER AND SHIPPING TIME QUEUE
;
      BCM DELAY:TRIA( 5,15,30);     ORDER & SHIPPING TIME
          RELEASE:SPARE;
          TALLY:SPARE TAT WITH BCM,INT(TimeIn):DISPOSE;
END;
```

The experimental frame is as follows:

```
BEGIN;
PROJECT,REPAIR,G.LEOPARD;

ATTRIBUTES:TIMEIN;

QUEUES:SPAREQ;

RESOURCES:SPARE,3;

TALLIES:TIME IN SYSTEM,10:
        RP TAT:
        SPARE TAT WITH BCM;

DSTAT:NQ(SPAREQ),AWAIT INSTALLATION:
      NR(SPARE),RFI ITEM INSTALLATION UTIL;

REPLICATE,2,0,1095,NO;

END;
```

APPENDIX D

GLOSSARY OF ACRONYMS

AIMD	Aircraft Intermediate Maintenance Department
AMRR	Aviation Material Readiness Report
A_o	Operational Availability
$A_o(i)$	Operational Availability of the aircraft based on the availability of the component
$A_o(rp)$	Operational Availability of the aircraft based on the availability of the components within the rotatable pool
ASO	Aviation Supply Office
AVCAL	Aviation Consolidated Allowance List
AVDLR	Aviation Depot Level Repairables
AWP	Awaiting Parts
BCM	Beyond Capability of Maintenance
COMNAVAIRPAC	Commander Naval Air Force U.S. Pacific Fleet
COSAL	Consolidated Shipboard Allowance List
CV	Aircraft Carrier
CVW	Carrier Airwing
DMR	Defense Management Review
DMRD	Defense Management Review Directive

DoD	Department of Defense
FMC	Fully Mission Capable
IMEC	Individual Item Esstentiality Code
LRCR	Local Repair Cycle Requirement
MC	Mission Capable
MDT	Mean Downtime
MTBM	Mean Time Between Maintenance
NALDA	Navy Automated Logistics Data Center
NMC	Not Mission Capable
NMCS	Not Mission Capable because of Supply
Non-RFI	Not Ready for Issue
O&ST	Order and Shipping Time
OSD	Office of the Secretary of Defense
PMC	Partially Mission Capable
PMCS	Partially Mission Capable because of Supply
RFI	Ready for Issue
RO	Requisition Objective
RP	Rotatable Pool
SAF	Support Action Form
SAL	Shipboard Allowance Level
SPCC	Ships Parts Control Center
SUADPS	Shipboard Uniform Automated Data Processing System

TAT	Turn Around Time
TYCOM	Type Commander
USN	United States Navy
VIDS/MAF	Visual Information Display / Maintenance Action Form

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